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A charge Controller Based on Microcontroller In Stand-alone Photovoltaic Systems

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Abstract

PV systems have spread widely all over the world. Charge controllers are needed to improve the efficiency of the PV systems and to protect the storage batteries. The main function of charge controller in PV systems is to charge the battery without permitting over charge and deep discharge. An intelligent charge controller has been designed with the object of prolonging battery life. The need for and advantages of such charge controllers are discussed and tests have been performed and applied on prototype which is versatile and has provision for more monitoring and control functions than that of the conventional logic and relay controller.

*Keywords:*Stand-alone PVsystem; Pulse Width Modulation; Microcontroller;

1. INTRODUCTION

Batteries account for most PV system failures, to keep these failures in low level, charge controller must be used. In general, there are two basic designs which control the charging of batteries from PV modules: Shunt Controller designs and Series Controller designs.

There are two modes of charging batteries:

- On-Off charging mode: It has been found that batteries charged with the standard set- points in this mode will reduce their capacities (55% to 60 %) of nominal capacities after one year at most, and this causes sulfating of the battery plates which in turn reduces charge efficiency.
- Pulse Width Modulation (PWM) charging mode: is the most effective means to achieve constant voltage battery charging by switching between on and off with certain frequency and a variable duty cycle the output current of PV modules to the batteries. The result is higher charging efficiency, rapid recharging, and healthy battery at full capacity. In addition this mode of solar battery charging promises some very interesting benefits which can be summarized as follows:

- Ability to recover lost battery capacity and desulfate battery.
- Increase the charge acceptance of the battery. -
- Maintain high average battery capacities (90% to 95%).
- Reduce battery heating and gassing.
- Charge efficiency can be improved and effects of aging can be reduced.
- Increase life of battery.

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2. THE CHARGE CONTROLLER BASED ON MICROCONTROLLER

The PWM (series – shunt) charge controllers which are based on microcontrollers are designed and manufactured in HIAST. An Atmel microcontroller AT89C2051 with 2kB flash memory was used as shown in Fig.1 Crystal oscillator of 8MHZ clocked the microcontroller. A power MOSFET (IRF640) was used as the solid-state switch for both charge-discharge lines. Schottky diodes block the reverse current flow when the panel voltage drops below the battery Voltage. Light emitting diode of two colours was used to display the system status. Over-voltage protection was implemented by connecting surge absorber (VE13 0750) between the high voltage power points and ground. The ALS75V25A simulator was used instead of PV panel which gives an open-circuit voltage of 21V, a short-circuit current of 10.5A and a maximum power output of 200W. The battery which was used in this test was a lead acid battery (VRLA-AGM) (12V/100Ah).

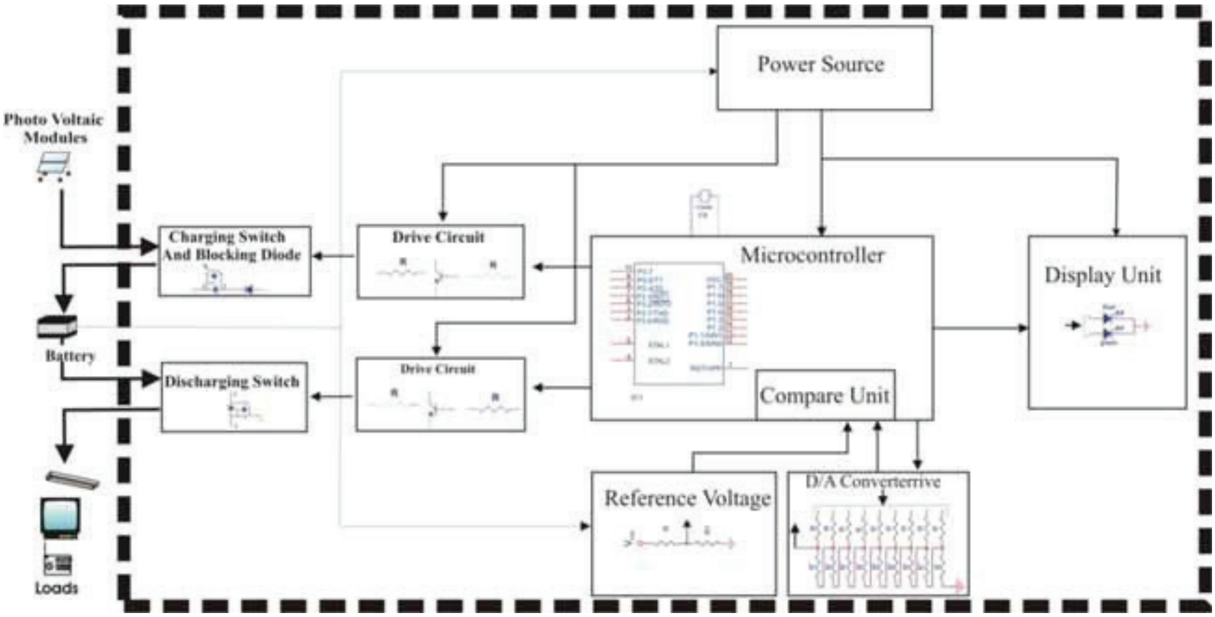

Fig. 1: Block diagrams of charge controller.

3. VOLTAGE CONTROL ALGORITHM

The charge controller, as shown in Fig. 2, allows the battery to be charged at full PV charging array current from the lower set-point battery voltage (LVD) up to the gassing set-point, Vg, where the program then uses pulse-width modulation (PWM) to control the charging current. At high voltage disconnect (HVD); the panel is disconnected to prevent the battery from being over-charged. The high and the lower set-point are not necessarily kept constant but may be manipulated by the software for optimized operation. Conversely, if the voltage of discharging battery falls below LVD, the load is disconnected. The choice of load reconnect voltage set-point (LVR) should be allowed to accumulate enough charge for the next discharge cycle. Table1 shows the operation sequence of battery system (charge - discharge).

Table 1: Charge control operations

Constraint	Action	Indicator
$V_{bat} \geq$ HVD(14.4V)	Stop charging by decreasing the charging current, i.e. PWM duty cycle to zero	Green LED on
HVD $> V_{bat} \geq V_g$(13.5V)	Controlled charging using PWM	5 blink green led
$V_{bat} < V_g$	Full current charging	Blinking(green or red) LED
$V_{bat} \geq$ LVR(12.6V)	Load reconnect	2- 4 blinks green led
$V_{bat} \leq V_{low}$(12.1V)	load reduction state	4-5 blinks red led
$V_{bat} \leq$ LVD(11.7)	Load disconnect	(green and red)led on

4. Practical Operation System

The charge controller measures the battery voltage levels and reacted to it due to flow chart shown in Fig.2. The battery voltage is cycled between HVD and LVD as shown in table2. With PWM, the charging current is reduced nearly to zero just before the HVD was reached. This minimizes the apparent drop in voltage which enables the microcontroller to monitor the actual battery voltage. During the cycling operation between HVD and LVD the charge controller consumed about 45mA. This is still good within the maximum of 100mA as recommend.

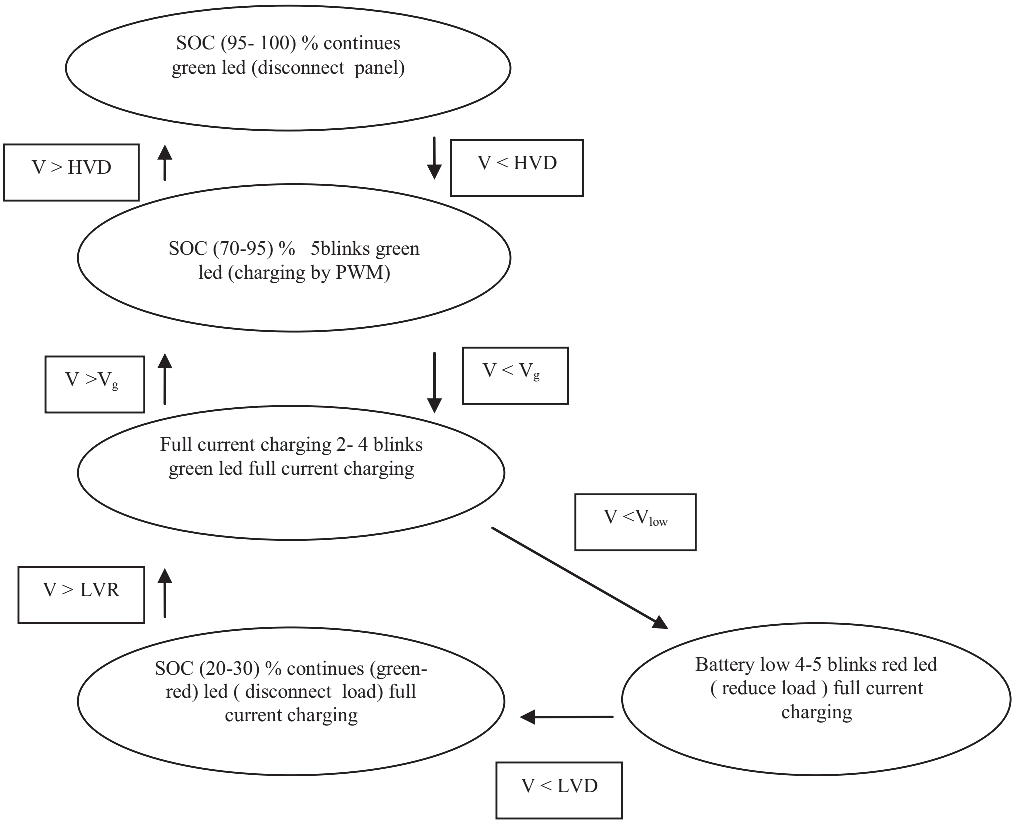

Fig.2: The flow chart of the battery charge management.

5. EXPRIMENTAL RESULTS

The measured values of set- points is shown in table2, comparing to table1 shows that the charge

Table 2: Test results of voltage set-point of the charge controller based on microcontroller

Control set- point	Measured voltage	Indicator	Comment
HVD	14.4	Green	Battery full
V_g	13.49	5 blink green led	PWM charging
LVR	12.58	2 blink green led	Battery good
V_{low}	12.07	4-5 blinks red led	Battery low
LVD	11.68	Green and red led on	Battery empty

Controller based on microcontroller is accurate and reliable and could be altered within the program as needed. Figure3 shows the variation of the current and the battery voltage during the charging process. The PWM mode as shown in Figure3 reduces the charging current to 16% of full panel current while battery voltage is maintained constant.

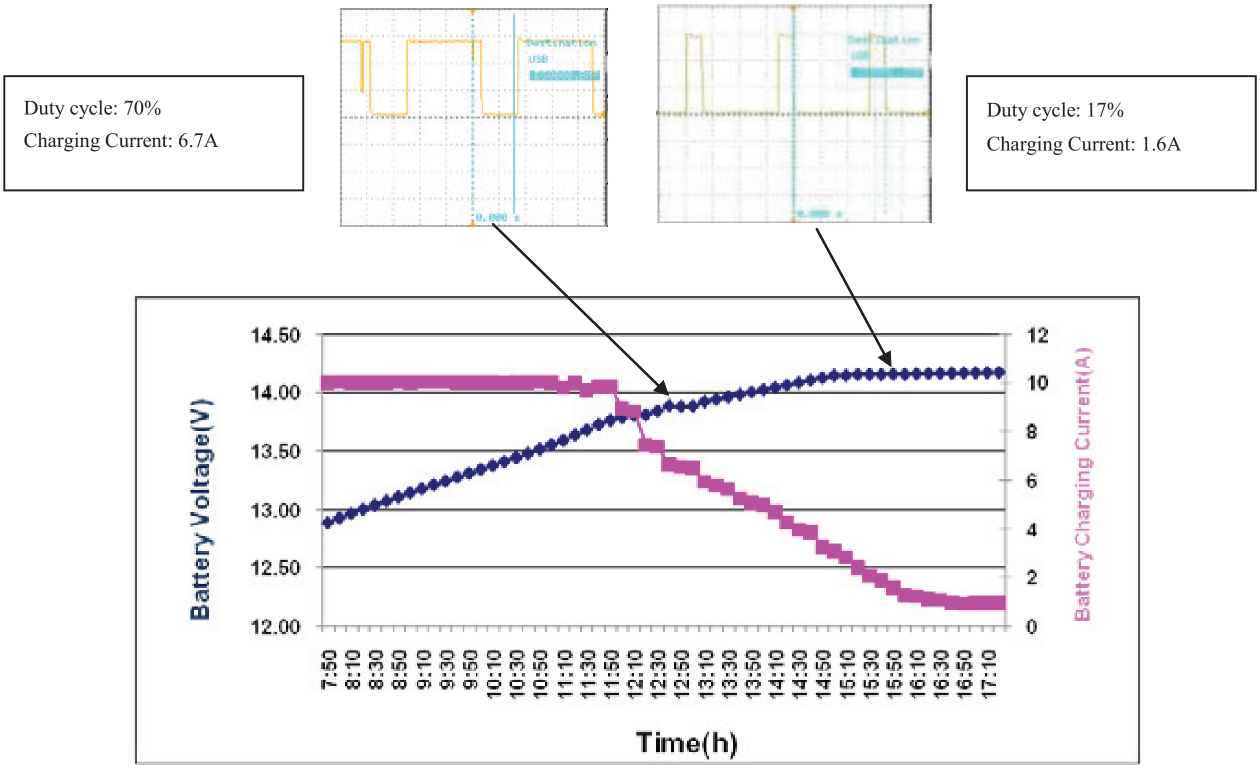

Fig.3: The battery charging curve using the charge controller.

6. CONCLUSION

- Charge controller by using a microcontroller simplifies the system in many ways:

a. Analogue -type feed- back circuitry is avoided as control is incorporated in a software programm designed specifically for user requirements.
b. Much more sophisticated procedures can be implemented.
c. A reduction in power consumption for charging battery is achieved.

- Using Microcontroller to build charge controller gives flexibility to the designer through:

a. Easy way to adjust the set-point values according to battery type.
b. Easy way to change the algorithm of charging battery by change some parameters in the program which installed in the Microcontroller.

- PV-lab in HIAST is working now for design the charge controller based on advance Microcontroller which can do more necessary functions such as:

a. Use Maximum Power Point Tracking method to achieve an effective way for charging batteries in short time.
b. Use LCD to display the measurement values of battery voltage, current and power.
c. Use the temperature compensation technique to achieve a high state of charge.

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